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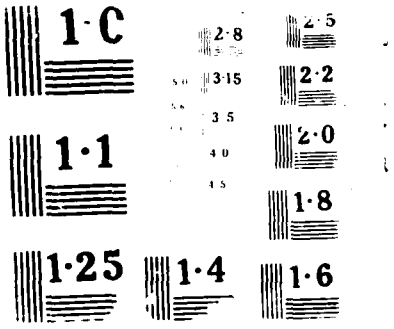
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# Experimental Studies of the Survival of Zooplankton: Short Term Effects of High Population Densities in an Artificial Environment

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

Net samples of live zooplankton were collected from Fishers Island Sound in mid-December 1984 for the purpose of determining the mortality due to net capture and the short-term effect on organism survival of high population densities in an artificial environment.

The contents of two series of five net tows each were placed in two separate insulated coolers containing 30 liters each of filtered sample-site water. The resultant concentrations in the two containers were equivalent to $7.2 \times 10^6$ and $15.65 \times 10^6$ of live organisms per $m^3$, respectively. (Counts of living and deal individuals in sub-samples withdrawn periodically from container 1 and 2 revealed mean mortality rates of 24 and 18 percent, respectively, over the first 8 hours after capture with an overall mean mortality of 21 percent. Twenty-six hours after capture overall mortality averaged 58 percent and after 47 hours all organisms were dead.)

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Net mortality, which was estimated from counts made at 2.5 and 3 hours after capture averaged 17 percent in each container.

During the course of the experiments it became clear that tidal currents can markedly influence the volume of water filtered by each net tow as well as the total content of zooplanktonic organisms.

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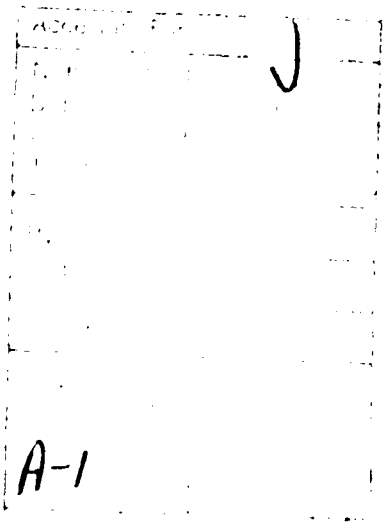

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# EXPERIMENTAL STUDIES OF THE SURVIVAL OF ZOOPLANKTON: SHORT TERM EFFECTS OF HIGH POPULATION DENSITIES IN AN ARTIFICIAL ENVIRONMENT

## INTRODUCTION

In 1982, experiments were conducted to determine the long and short term effects of capture, transportation and various conditions of crowding in an artificial environment on the survival of zooplanktonic organisms (Brooks and Brown, Jan 1985, NUSC TR 7479)

From results of these experiments mortality due to net capture was estimated to be 36 percent though the data suggest that this estimate may be somewhat high. A concentration equivalent to $18.6 \times 10^6$ zooplankters per $m^3$ was highly detrimental to the survival of these creatures but at concentrations equivalent to 2,4 and $6 \times 10^6$ per $m^3$ the ability of the zooplankton to survive is good and appears to be independent of these concentrations, at least for a period up to 21 hours in duration. Longer term experiments showed that at concentrations equivalent to $6 \times 10^4$ per $m^3$ survivability of zooplankters decreased only slightly over an 8 day period.

During actual tow-tank seeding operations there will be obvious advantages in time and effort if live zooplankton can be transported successfully from the sample site to the tow-tank in a highly concentrated condition. As mentioned, earlier experiments indicated that there were negligible deleterious short term effects at concentrations of $6 \times 10^6$ organisms per $m^3$. A natural extension of these experiments would be to determine the short-term effects of even higher concentrations. The following report presents results of such experiments conducted in December, 1984.

## OBJECTIVES

The basic objective was to determine the short-term (i.e. 8 hours) effects on live zooplankton of concentrations on the order of $10 \times 10^6$ organisms per $m^3$. A secondary objective was to obtain an additional estimate of mortality due to net capture.

## METHODS

This experiment was conducted in essentially the same manner as was reported by Brooks and Brown, 1985 (op. cit.). Samples were collected from an area off Seaflower Reef in Fishers Island Sound on the 18th and 19th of December, 1984 using the R/V "Libinia". Collections were made with a metered, 1-foot diameter, number 10 mesh (mesh opening 153 μm) net which was towed at approximately 2 1/2 knots at a depth of about 2 meters. Two net tows were taken on the 18th to provide samples for: 1. determination of species composition, and 2. estimation of the population density at the sample site. The duration of the first tow was four minutes, five seconds; the second tow lasted eight minutes, five seconds. Volume of water filtered was 24.5 and 50.9 $m^3$, respectively. Net contents were washed into separate gallon jars containing filtered sample-site water and the volume was brought up to 3800 ml. Samples were then transported to the laboratory and replicate, 10 ml subsamples were examined under the microscope. Over 95 percent of the organisms were copepods and counts of four replicates from each jar indicated an overall mean number of 1400 zooplankters per $m^3$ at the sample site. Using this estimate of population density and assuming a 20-25 percent net mortality, calculations showed that slightly more than 250 $m^3$ of sample-site water would need to be filtered to capture enough zooplankton to create a concentration in the 30-liter insulated coolers equivalent to $10 \times 10^6$ organisms per $m^3$.

The following day (19 Dec. 84) two series of five net tows each were collected from the sample site. The net tow log for these collections is shown in Table 1. The contents of each series were washed into two separate insulated coolers which had been filled previously with filtered sample-site water. Total water volume in each cooler was adjusted to 30 liters. These coolers were then transported back to the laboratory where subsamples were periodically removed for examination and counting.

## RESULTS AND DISCUSSION

As shown in Table 1 the total volume of water filtered during the first series of net tows was 257 $m^3$; the second series filtered 233 $m^3$. The contents of these tows were placed in 30-liter containers numbered 1 and 2, respectively.

A concerted effort was made to reduce between-tow variability by: 1. making all tows at the same engine throttle setting 2. towing in the same direction and manner (i.e. against the tide), 3. towing in a relatively open water area which by outward appearances looked homogeneous 4. towing the same net, and 5. making the duration of each net tow as close to the same as possible. In spite of these precautions some notable differences occurred between the two series and especially between the individual net tows in the second series. As will be shown later, there were also rather large differences between the two series in the total number of organisms captured. The most logical explanation to account for these differences is

Table 1

NET TOW LOG FOR SAMPLES COLLECTED
ON 19 DECEMBER 1984

| TOW NO. | LOCAL TIME START (Hour. Sec.) | LOCAL TIME END (Hour. Sec.) | DURATION OF TOW (Sec) | DISTANCE TRAVELLED (m) | KNOTS | VOL. FILT'D ($m^3$) | CONTAINER NO. |
|---|---|---|---|---|---|---|---|
| 1 | 0841.48 | 0850.00 | 492 | 640 | 2.5 | 51.2 | 1 |
| 2 | 0853.43 | 0901.48 | 485 | 639 | 2.5 | 51.1 | 1 |
| 3 | 0905.40 | 0913.51 | 491 | 630 | 2.5 | 50.5 | 1 |
| 4 | 0919.00 | 0927.01 | 481 | 664 | 2.7 | 53.1 | 1 |
| 5 | 0939.33 | 0947.40 | 487 | Flow Meter Fouled | - | 51.1 (EST'D) | 1 |
| | | | | | TOTAL | 257 | |
| 1A | 0952.11 | 1000.17 | 486 | 642 | 2.6 | 51.4 | 2 |
| 2A | 1004.30 | 1012.36 | 486 | 576 | 2.3 | 46.1 | 2 |
| 3A | 1022.25 | 1030.29 | 484 | 624 | 2.5 | 49.9 | 2 |
| 4A | 1035.23 | 1043.24 | 481 | 579 | 2.3 | 46.4 | 2 |
| 5A | 1047.26 | 1055.31 | 485 | 492 | 2.0 | 39.3 | 2 |
| | | | | | TOTAL | 233 | |

related to the tidal cycle and the influence which it exerts on the current flow and particulate distributions at the sample site. According to National Ocean Survey Tidal Current Tables, the time of "slack water, ebb begins" at this station on the 19th of December 1984 was 0809 hours. The maximum velocity of the ebbing current, which flows in an easterly direction, occurs approximately 3 1/2 hours later. Net tows were begun at 0841 and were completed at 1055. During this period tidal current velocity was presumably increasing to its maximum which could be expected to occur at about 1130 hours. Data listed in Table 1 for the first series of net tows show only slight differences between tows in distance travelled, towing speed and volume of water filtered. During the second series of tows, however, (as the tidal current was building) though the duration of all five net tows differs by only five seconds there is, in general, a decreasing trend in distance travelled, speed of tow and volume of water filtered. Since all towing was made against the current and at the same engine throttle setting, vessel speed and therefore net velocity and distance travelled, would decrease (as the data suggest) as tidal current velocity increased. A secondary effect of these circumstances is that water with different particulate content distributions (probably influenced by Thames River effluent) was being carried into the sampling area during the 2 1/4 hour period of net tow collections. Coincident with the apparent increase in particulate content of the water there may also have been some clogging of the net though it is not possible to separate this effect from effects due to reduced towing speeds.

At approximately 3, 4, 6, 8, 26, and 47 hours after capture of the organisms, two replicates of 5 ml each were removed from each cooler and examined under the microscope. Counts of live and dead zooplankton were made in the same manner as described by Brooks and Brown, 1985 (op. cit.). Results of these counts are shown in Tables 2 and 3. A summary of these tables is shown in Table 4.

The counts which are of particular interest are those taken over the first eight hours after capture since this is the length of time organisms may have to reside in transportation containers before they are finally transferred to the tow-tank. The estimates for number of live zooplankton and percent survival/mortality over the first eight hours given in Table 4 are means of the replicate counts made at 3, 4, 6, and 8 hours after capture. The estimated number of live zooplankton in container 1 is less than one half that in container 2. The probable cause for this difference is an enrichment of the sampling area during the latter half of the collection period due to tidal flow as discussed earlier. These figures result in equivalent concentrations of $7.2 \times 10^6$ and $15.65 \times 10^6$ live zooplankton per $m^3$ in containers 1 and 2, respectively. Although the desired equivalent concentration of $10 \times 10^6$ organisms per $m^3$ was not achieved, the mean percent survival/mortality estimates indicate that for a period of eight hours such a concentration would not result in an unacceptably high mortality rate. Counts made 26 hours after capture revealed a markedly elevated mortality and at the end of 47 hours all organisms were dead.

In addition to the physical trauma and physiological shock caused by net capture it is well known that zooplanktonic organisms are relatively sensitive to temperature change, especially if the change is a rapid one. The temperature history of the coolers shows that three hours after capture water temperature was 50°F or 1° higher than the water at the sample site. By the time the eight-hour count was made the water temperature had risen only to 52°F. Twenty-six and forty-seven hours after capture the temperature had risen to 59 and 64°F, respectively. These latter temperatures, working in concert with the high population densities, undoubtedly lowered the oxygen concentration of the water, probably below the critical level. To reduce these deleterious effects during actual tow-tank seeding operations plastic bags full of ice could be floated in the water in the transportation containers and the water could be aerated as well.

Experimental results from studies conducted in 1982 indicated a mortality due to net capture of 36 percent. In the present experiments an additional estimate was obtained by examining the counts of samples taken from containers 1 and 2 at 3 and 2 1/2 hours, respectively, after capture. The estimate for mean percent mortality in each container was 17 percent. Though this estimate includes mortality due to net capture as well as mortality that occurred in the two containers over the first 2 1/2 to 3 hours, experience gained from the 1982 studies suggests that most, if not all of this mortality was related to the trauma of net capture. The true estimate of mortality due to net capture probably lies somewhere between 36 and 17 percent and in future calculations of this nature a value of about 25 percent will be assumed.

Table 2

ZOOPLANKTON COUNTS FOR DETERMINATION
OF MORTALITY RATES

CONTAINER NO. 1

| ELAPSED TIME (Hrs) SAMPLE COLL'N TO SAMPLE COUNT | REPLICATE NO. | NUMBER DEAD PER 5 ML | NUMBER ALIVE PER 5 ML | TOTAL NUMBER PER 5 ML | % MORTALITY | EST'D TOTAL NO. IN 30L (ALIVE PLUS DEAD) | EST'D TOTAL NO. IN 30L (ALIVE ONLY) |
|---|---|---|---|---|---|---|---|
| 3 | 1 | 7 | 28 | 35 | 20 | 210,000 | 168,000 |
| | 2 | 6 | 36 | 42 | 14 | 252,000 | 216,000 |
| 4 | 1 | 18 | 42 | 60 | 30 | 360,000 | 252,000 |
| | 2 | 18 | 39 | 57 | 32 | 342,000 | 234,000 |
| 6 | 1 | 17 | 32 | 49 | 35 | 294,000 | 192,000 |
| | 2 | 8 | 45 | 53 | 15 | 318,000 | 270,000 |
| 8 | 1 | 12 | 26 | 38 | 32 | 228,000 | 156,000 |
| | 2 | 6 | 40 | 46 | 13 | 276,000 | 240,000 |
| Means 1st eight hours | | 11.5 | 36 | 47.5 | 24 | 285,000 | 216,000 |
| 26 | 1 | 19 | 15 | 34 | 56 | 204,000 | 90,000 |
| | 2 | 16 | 24 | 40 | 40 | 240,000 | 144,000 |
| 47 | 1 | 39 | 0 | 39 | 100 | 234,000 | 0 |
| | 2 | - | - | - | - | - | - |

TABLE 3

ZOOPLANKTON COUNTS FOR DETERMINATION
OF MORTALITY RATES

CONTAINER NO. 2

| ELAPSED TIME (HRS)-SAMPLE COLL'N TO SAMPLE COUNT | REPLICATE NO | NUMBER DEAD PER 5 ML | NUMBER ALIVE PER 5 ML | TOTAL NUMBER PER 5 ML | % MORTALITY DEAD) | EST'D TOTAL NO. IN 30L (ALIVE PLUS ONLY) | EST'D TOTAL NO. IN 30L (ALIVE |
|---|---|---|---|---|---|---|---|
| 2 1/2 | 1 | 16 | 66 | 82 | 20 | 492,000 | 396,000 |
| | 2 | 19 | 117 | 136 | 14 | 816,000 | 702,000 |
| 4 | 1 | 13 | 59 | 72 | 18 | 432,000 | 354,000 |
| | 2 | 11 | 94 | 105 | 10 | 630,000 | 564,000 |
| 6 | 1 | 22 | 70 | 92 | 24 | 552,000 | 420,000 |
| | 2 | 16 | 71 | 87 | 18 | 522,000 | 426,000 |
| 8 | 1 | 25 | 72 | 97 | 26 | 582,000 | 432,000 |
| | 2 | 12 | 77 | 89 | 13 | 534,000 | 462,000 |
| Means-1st eight hours | | 17 | 78 | 95 | 18 | 570,000 | 469,500 |
| 26 | 1 | 61 | 30 | 91 | 67 | 546,000 | 180,000 |
| | 2 | 68 | 29 | 97 | 70 | 582,000 | 174,000 |
| 47 | 1 | 105 | 0 | 105 | 100 | 630,000 | 0 |
| | 2 | - | - | - | - | - | - |

Table 4

A SUMMARY OF THE RESULTS OF ZOOPLANKTON CONCENTRATION EXPERIMENTS CONDUCTED BETWEEN 18-21 DECEMBER 1984

| | CONTAINER 1 | CONTAINER 2 |
|---|---|---|
| Est'd Mean Total No. of Live Zooplankton over 1st 8 Hr. Period | 216,000 | 469,500 |
| Equivalent Conc. of Live Zooplankton | 7,200,000/$m^3$ | 15,650,000/$m^3$ |
| Est'd Conc. of Zooplankton at Sample Site-all Presumed Alive | 1,109/$m^3$ | 2,446/$m^3$ |
| Mean Percent Survival/ Mortality Over 1st 8 Hr. Period | 76/24 | 82/18 |
| Mean Percent Survival/ Mortality After 26 Hours | 52/48 | 32/68 |
| Mean Percent Survival/ Mortality After 47 Hours | 0/100 | 0/100 |

## CONCLUSIONS

Concentrations of live zooplankton up to an equivalent of about 15 x $10^6$ organisms per $m^3$ for periods up to eight hours appear to have a negligible deleterious effect on the survival of these creatures, at least at water temperatures of about 50°F. Greater mortality can be expected at higher temperatures.

Measurements of mortality over the first 2 1/2 to 3 hours after capture averaged 17 percent of the total population. Experience gained from previous studies indicates that most, if not all of this mortality is due to the trauma of net capture. The difference between 17 percent and an earlier estimate for net mortality of 36 percent leads to the observation that a more realistic estimate for this variable may lie somewhere around 25 percent.

Measurements of mortality over a period of 8 hours averaged 24 percent in container 1 which contained organisms in a concentration equivalent to 7.2 x $10^6$ zooplankters per $m^3$. Mean mortality over this same period of time in container 2, with an equivalent concentration of 15.65 x $10^6$ organisms per $m^3$, was 18 percent.

Tidal currents in the sampling area had a marked influence on variability in water volume filtered and total content of captured organisms. Tidal effects should be accounted for in future studies

## RECOMMENDATIONS

1. Tow tank seeding operations should be carried out during the winter months when water temperatures are 50°F or less

2. Prior to tow tank seeding, comprehensive studies of the anticipated field sampling site should be conducted to determine the physical oceanographic parameters of pertinence and the characteristics of the resident biological population.

3. While being transported from the field to the tow tank live zooplankton can be concentrated up to an equivalent of 15x$10^6$ organisms per $m^3$ but temperature and dissolved $O_2$ of the water in which they reside should be carefully monitored.

# REFERENCES

Brooks, A. L. and C. L. Brown. 1985. Experimental studies of the survival of zooplankton: Effects of net capture and artificial control of population densities, NUSC TR 7479 Jan. 1985.

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